LETNIK 05 • ŠT. 01

2016 03

MAREC

svetstrojništva

Zveza Strojnih Inženirjev Slovenije

Mechanical EngineeringWorld

Association of Mechanical Engineers of Slovenia

PREDSTAVLJAMO:

- Digital human models
- Določitev karotidne arterije
- Prenova šolskih stavb v Ukrajini
- Slovenska akreditacija
- Bloom
- Prof. dr. Bojan Dolšak
- IFAM; INTRONIKA
- Sejem priložnosti
- Akademija strojništva 2016

ZSIS

UREDNIŠKI ODBOR

SVET STROJNIŠTVA

Na naslovnici: "3D - Karotidna arterija"
Odgovorni urednik: Iztok Golobič
Urednica: Andreja Cigale
Tehnični urednik: Žiga Zadnik
Lektoriranje: Andreja Cigale
Ime in sedež založnika: ZSIS, Karlovška cesta 3, 1000 Ljubljana
Leto izida publikacije: 2016
Leto natisa ali izdelave publikacije: letnik 05, št. 01
Število natisnjenih izvodov: 150
Informacije so točne v času tiska.
Preverite www.zveza-zsis.si za posodobitve.

Svet strojništva (ISSN-2350-3505), revija, je vpisana v razvid medijev, ki ga vodi Ministrstvo za kulturo RS, pod zaporedno številko 872. Revija je brezplačna za člane Zveze strojnih inženirjev Slovenije, podjetja, izobraževalne ustanove in drugo zainteresirano javnost na območju Republike Slovenije.

KAZALO

KAZALO

UVODNIK

UVODNIK
marec 2016

Spoštovani,

V tokratni številki revije Svet strojništva lahko preberete pogovor z dekanom Fakultete za strojništvo v Mariboru ter predstavitev Slovenske akreditacije in pogovor z njenim direktorjem. Kot zanimivost predstavljamo inovativen študentski projekt Bloom ter povzetek podelitve rektorjeve nagrade za naj inovacijo Univerze v Ljubljani. V novi rubriki Znanost na dlani pa lahko preberete tri kratke znanstvene prispevke.

Prijetno branje!

Uredništvo
Svet strojništva

ZVEZA STROJNIH INŽENIRJEV SLOVENIJE WWW.ZVEZA-ZSIS.SI

STROŠKOVNO IN ENERGETSKO UČINKOVITA PRENOVA ŠOLSKIH STAVB V UKRAJINI

COST AND ENERGY EFFICIENT MODERNIZATION OF SCHOOL BUILDINGS IN UKRAINE

Henrik Gjerkeš[a,b], Marjana Šijanec Zavrl[a], Tetiana Rapina[c*]
[a]Building and Civil Engineering Institute ZRMK, Dimičeva 12, 1000 Ljubljana, Slovenia
[b]University of Nova Gorica Vipavska 13, 5000 Nova Gorica, Slovenia
[c]O.M Beketov National University of Urban Economy in Kharkiv, Kulikivskyi uzviz str.12, 61002 Kharkiv, Ukraine

**Corresponding author: Tetiana Rapina*
O.M Beketov National University of Urban Economy
in Kharkiv
Faculty of Civil Engineering
Kulikivskyi uzviz str.12
61002 Kharkiv
Ukraine

Tel: +380971952109
E-mail: tvrapina@gmail.com

Mechanical Engineering World – 14
Journal homepage: www.zveza-zsis.si/

Article info
Article history:
Received 1 March 2016
Received in revised form 4 March 2016
Accepted 25 March 2016
Available online 31 March 2016

Kratki znanstveni prispevek / Short scientific paper

Izvleček

Izboljšanje energetske učinkovitosti obstoječih stavb v EU ima velik potencial pri naporih za zmanjšanje rabe energije in je brez dvoma pomembna tema tudi za Ukrajino. V članku smo analizirali pomembnost prenove stavb javnega sektorja s posebnim poudarkom na šolskih stavbah. Uporabili smo metodologijo stroškovnega optimum za oceno ne zgolj ekonomskih, ampak tudi okoljskih in družbenih učinkov prenove stavb šolskega fonda. Pri iskanju optimalne ravni energetsko učinkovite prenove šolskih stavb v Ukrajini smo uporabili evropske in slovenske izkušnje. Pokazali smo, da je trajnostna prenova s smernicami za skoraj-nič energijsko stavbo (sNES), kot so definirane v evropskih predpisih, izvedljiva z dobrimi rezultati in je priporočljiva tudi za prenovo šolskih stavb v Ukrajini.

Ključne besede: stroškovna optimalnost, energetska učinkovitost, skoraj-nič energijska stavba, ovoj stavbe, ogrevanje

Abstract

Improvement of the energy efficiency of existing buildings in EU has great potential in the efforts to reduce energy consumption, which is with no doubt relevant issue also for Ukraine. In this article the importance of public building stock modernization was analysed with special focus on school buildings. The optimal cost methodology was used to evaluate not only the economic, but also environmental as well as social effects of school building stock modernization. In searching for the optimal level of energy-efficient modernization of school buildings in Ukraine, the European and Slovenian experiences were used. It is demonstrated that the sustainable reconstruction with the nearly-Zero Energy Building (nZEB) guidelines, as defined in EU regulations, is feasible with good results and can be recommended also for reconstruction of school buildings in Ukraine.

Key Words: *cost optimum, energy efficiency, nearly zero energy building, building envelope, heating*

1. Introduction

The energy efficiency indicator of Ukraine's economy is 54.2% of the average EU level according to the rating «Ukrainian Energy Index in 2013» [1]. The main energy consumer in Ukraine is building sector that consumes more than half the energy. Energy saving potential of buildings is estimated to 9 million 238 thousands of tonnes of oil equivalents, which corresponds to 11.4 billion m^3 of natural gas.

Most of the buildings in Ukraine require substantial modernization. More than 80% of the buildings were built in 1960-1970. They were constructed according to USSR building codes, issues of energy efficiency in the building were not considered as a priority. At the time saving building materials and reducing construction time was in the first place. The government reduced capital costs and at times increased operating costs. Country was rich in natural resources and general opinion was that it will be enough cheap fuel for the country, if not forever, then at least for the very long time.

However, with the independence of Ukraine the situation has changed dramatically, which was particularly acute in recent years. The problem of essential dependence on expensive imported energy resources has jeopardized the question of Ukraine's independence.

Therefore, issues related to the energy efficiency of existing buildings are become especially relevant for Ukraine. The objective of presented study is the existing public building stock with the focus on school buildings. At present, the buildings modernization is performed with the minimum established regulatory requirements for energy efficiency of buildings in Ukraine. The compliance with these requirements allows 2-3 times reduction of the the energy consumption and reach a final energy consumption rate in the range of 80-100 kWh/m^2, but it is still significantly higher than the standards valid for the EU countries, and also Slovenia, especially when compared to the Directive 2010/31/EU, EPBD recast [2] and nearly-zero energy building (nZEB) guidelines.

The aim of presented analysis is to find the optimal level of energy-efficient modernization of school buildings in Ukraine based on European and Slovenian experiences in this area.

2. Methods

The procedure developed in [3] was used to find the optimal level of energy-efficient modernization, which involves systematic and reliable scientific seven-step procedure, including:

1. Selection of the reference building/buildings;
2. Definition of construction concepts based on building envelope optimization for fixed four specific heat loss levels (from business as usual construction to highly insulated building envelope);
3. Specification of building technical systems;
4. Energy simulations for specified construction concepts;
5. Post processing of the simulation results to calculate delivered, exported and primary energy;
6. Economic calculations for construction cost and net present value calculations;
7. Sensitivity analyses for interest rate, escalation of energy prices and other parameters.

Energy calculations were performed in this study for the 6 building concepts, according to the methodology [4]. Construction concepts have been described in Section 2.2.

2.1 The reference buildings

In the study typical school building in Ukraine, built in 1960-1970s has been considered. This is 3-and 4-storey frameless buildings, with load bearing brick walls 510 mm of thickness. Overlaps and roof were built from prefabricated hollow core slabs. Windows in buildings are predominantly wooden, partially were replaced by metal and plastic fitted with simple single glass units. Buildings are connected to municipal district heating from main gas heat station. Only natural ventilation is provided, without mechanical ventilation system.

The average rate of delivered energy need for heating of typical school building is about 200 kWh/(m^{2}a), and this value is used for further calculations.

Average electricity consumption was determined by averaging the values from energy audits for similar objects and amounts to 12 kWh/(m^{2}a).

2.2 Definition of construction concepts

In the analysis, six construction concepts were used, in which the building envelope energy performance levels was varied.

The considered construction concepts were:

1. **Existing building;**
2. **Modernization of buildings to the level of the DBN requirements "The thermal insulation of buildings."** Envelope specifications: 10 cm EPS-insulation for walls (in common U=0.30W/m²K); 18 cm mineral wool insulation for roof (in common U=0.19W/m²K); 10 cm EPS-insulation for ground floor (in common U=0.27 W/m2K); windows replacement (U=1.33W/m²K).
3. **An intermediate variant between options of modernization buildings №2 and №5.** For the building was provided: 20 cm EPS-insulation for walls (in common U=0.17W/m²K); 32 cm mineral wool insulation for roof (in common U=0.14W/m²K); 25 cm EPS-insulation for ground floor (in common U=0.14 W/m²K); windows replacement (U=0.9W/m²K).
4. **An intermediate variant between options of modernization buildings №2 and №5.** Envelope specifications: 25 cm EPS-insulation for walls (in common U=0.14W/m²K); 50 cm mineral wool insulation for roof (in common U=0.09W/m²K); 45 cm EPS-insulation for ground floor (in common U=0.09 W/m²K); windows replacement (U=0.8W/m²K).
5. **Modernization of buildings to the level of nZEB.** This determination of nZEB was formulated in accordance with case, which comply with standards established in Slovenia [6].
   - Envelope specifications: 35 cm EPS-insulation for walls (in common U=0.10W/m²K); 80 cm mineral wool insulation for roof (in common U=0.06W/m²K); 70 cm EPS-insulation for ground floor (in common U=0.06 W/m²K); windows replacement (U=0.7W/m²K).
   - Heating system specification: air-to-water heat pump;
   - Placement on the roof solar panels that generate electricity in the amount of 3,8 kWh/(m²a).
   - The heat pump and the solar panels provide more than 50% from renewable energy sources (RES) of energy used by building, as required for nZEB in Slovenia.
6. **The modernization of the building to the level of ZEB.**

- Envelope specifications: 45 cm EPS-insulation for walls (in common U=0.07W/m²K); 80 cm mineral wool insulation for roof (in common U=0.06W/m²K); 70 cm EPS-insulation for ground floor (in common U=0.06 W/m²K); windows replacement (U=0.6W/m²K).
- Heating system specification: air-to-water heat pump;
- Placement on the roof solar panels that generate electricity in the amount of 18,1 kWh/(m²a).

The heat pump and the solar panels provide more than 100 % from renewable energy sources (RES) of energy used by building, thus ensuring a zero balance of energy consumption.

In all variants the building is equipped with the mechanical ventilation system with heat recovery for energy efficient conditioning of the air in the classroom.

In Ukraine, very often the modernization of schools and kindergartens begins with replacement of wooden windows for cheap metal and plastic windows with single chamber units (U = 2.5 W/m²K). At the same time reducing energy consumption is achieved by increasing the airtightness of buildings in connection with more controllable ventilation regime.

2.3 Energy simulations for specified construction concepts

Energy calculations were performed for the 6 building concepts, according to the methodology, described in [4].

2.4 Post processing of the simulation results to calculate delivered, exported and primary energy

To calculate primary energy, the delivered energy was reduced for on-building generated energy and multiplied with Primary energy values. Primary energy values (ET-values) were calculated with Estonian primary energy factors which are:

- electricity 2,5;
- district heating 0,9;
- renewable fuels 1.

2.5 Economic calculations, construction cost and net present value calculations

The cost of a building's life cycle was considered during 30 years. The calculations were taken into account the cost of materials, work and equipment maintenance for:

- building insulation;
- heating modernization;
- equipping ventilation system;
- installation of solar panels.

The operating (used energy) cost consider the current Ukrainian prices:

- Electricity 0.0497 € /kWh + VAT (20 %).
- District heating 0.0443 €/kWh + VAT (20 %).

2.6 Sensitivity analyses

In the calculations assumed interest rate of 6 %, which corresponds to the parameters of financing program «NEFCO» [5], which is currently the most accessible fond for the realization of the public sector buildings modernization in Ukraine. The interest rate for energy efficiency program loans from state banks in Ukraine is at least 10%. In order to show sensitivity to the escalation rate in the study were considered three escalation versions: 4 %; 6 % and 8 %, as showed in Figures 2-4.

3. Results and discussion

The calculation results show that increasing insulation as provided from 1st to 6th concept of the building envelope together with windows replacement decrease heat losses significantly, and consequently the final energy consumption for heating from 200 to 17 kWh/(m²a), Figure 1.

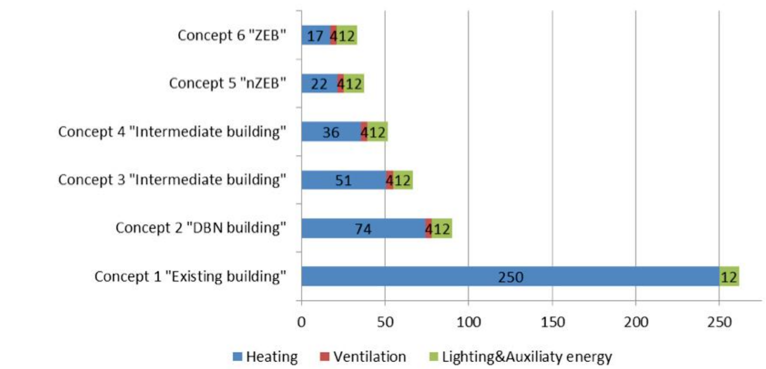
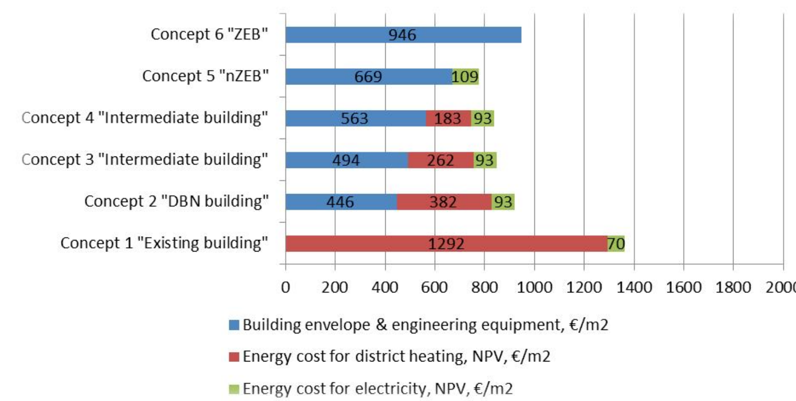
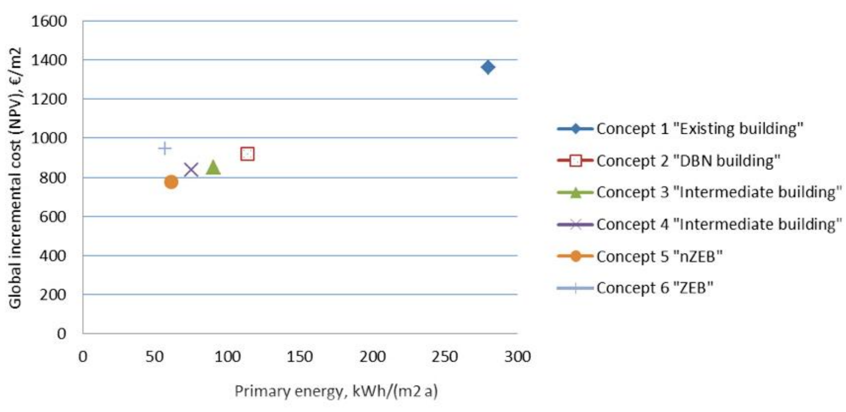


Figure 1: Concepts and simulated delivered energy, kWh/(m²a)





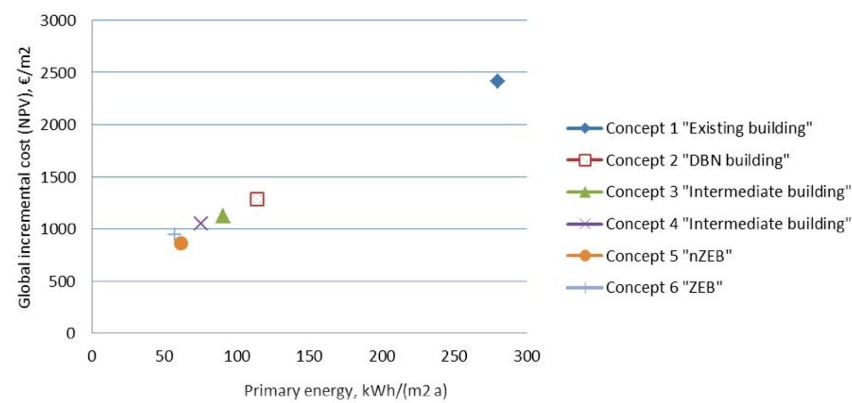
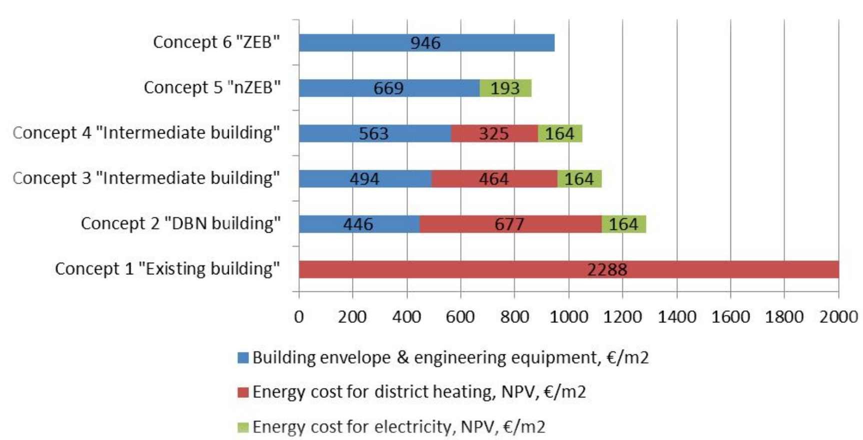
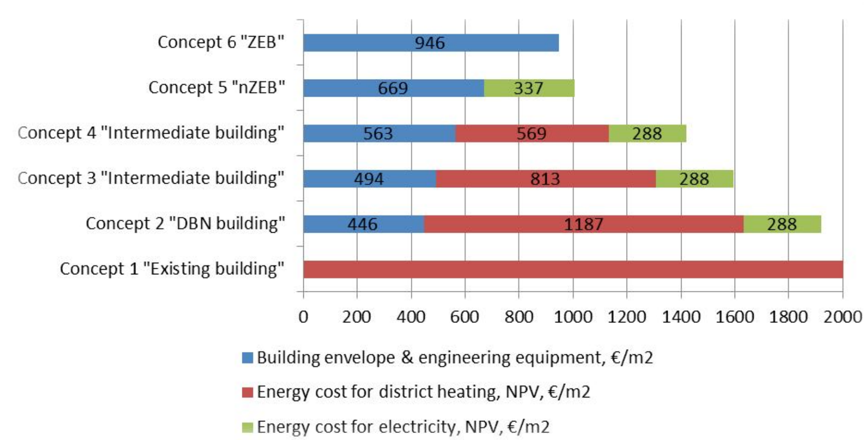


Figure 2: Global incremental cost calculation (the real discount rate of 6 % and the escalation 4 %) for 30 years life time period.

Figure 3: Global incremental cost calculation (the real discount rate of 6 % and the escalation 6 %) for 30 years life time period.





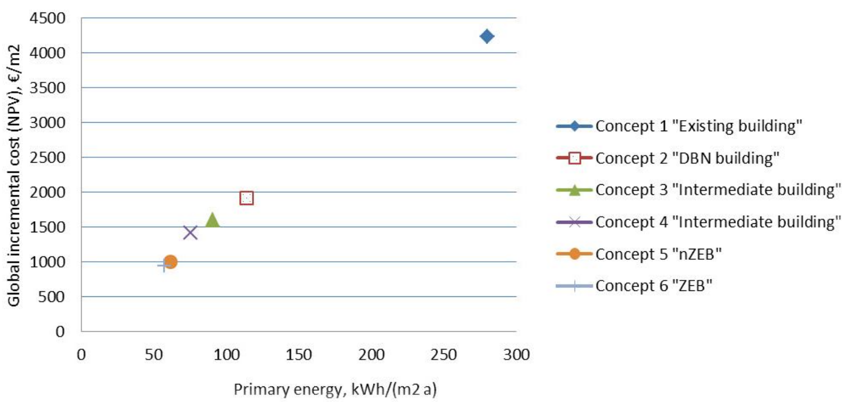


Figure 4: Global incremental cost calculation (the real discount rate of 6 % and the escalation 8 %) for 30 years life time period

The best option is the concept 5: nZEB, wherein a high level of initial investment is compensated by a low operational and maintenance costs.

In Figures 2-5 it can be seen that the modernization of the building with the nZEB standards require significantly greater initial investment in comparison with the traditional concept 2: DBN. However, in spite of that, and even at the high discount rate, for the whole life cycle cost, the nZEB building reaches a cost optimum among all 6 analysed building concepts in Ukraine, as well as in the EU, with the effective rate of no more than 3 %.

Concept 6: ZEB concedes concept 5 mainly due to the need to install expensive, more powerful solar power station, which requires 41 % of the initial investment.

However, this option might become optimal over time with a significant reduction of the solar panels price in the future.

In general, it can be seen that the results are sensitive to the interest rate, and from an economic point of view solely, it can be seen that at an effective rate of 4 % modernization becomes unattractive.

However, in any case the social importance of school building stock, the energy wastefulness of present state and the cost optimisation require holistic approach for cost and energy efficient modernization of school buildings in Ukraine, and analysis show, that the economic and environmental optimal way to do that is to use nZEB standards.

4. Conclusion

Considering that in Ukraine more than 80 % of the buildings (including school buildings) requires modernization is very important to choose the correct modernization option. We propose that it is advisable not to focus on the minimum requirements established in Ukraine,

but strive for the implementation of relevant cost and energy efficient European requirements. It will allow to come nearer to the European level of building energy efficiency.

The important point are also the environmental benefits of the school building stock modernization, as if used the nZEB standards it reduces the CO_2 emission by more than 80 % in the case used in this analysis. The social factor is demonstrated through better comfort and healthy microclimate in the modern environmentally friendly buildings, which is necessary for children and teachers comfortable staying. Pupils will have opportunity to learn and generate careful attitude to the energy and natural resources.

This study shows, that the sustainable reconstruction with the nearly-Zero Energy Building (nZEB) guidelines, as defined in EU regulations, is feasible with good results and can be recommended also for reconstruction of school buildings in Ukraine

References

[1] Energy efficiency rankings of the regions of Ukraine 2013.http://energy-index.scm.com.ua/media/report/pdf/_UEI_13_ENG.pdf

[2] EPBD recast: Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (recast). http://ec.europa.eu/energy/efficiency/buildings/buildings en.htm; http://eurlex.europa.eu/JOHtml.do?uri=OJ:L:2010:153:SOM:EN:HTML.

[3] J. Kurnitski, A. Saari, T. Kalamees, M. Vuolle, J. Niemel, T. Tark. Cost optimal and nearly zero (nZEB) energy performance calculations for residential buildings with REHVA definition for nZEB national implementation. Energy and Buildings, 43(11), (2011) 3279-3288,

[4] DBN B.2.6-31:2006 Thermal insulation of buildings. (2006) http://eurobud.ua/uploads/files/ pinoplast_norm_doc/4%20DBN%20B.2.6-31-2006.pdf

[5] Nordic environment finance cooperation/NEFCO / http://www.nefco.org/?language=en

[6] M. Šijanec Zavrl, G. Stegnar, H. Gjerkeš, Demonstration of the nearly zero energy building concept. Journal of Geoscience and Environment Protection (2015), in SciRes. http://www.scirp.org/journal/PaperInformation.aspx?PaperID=59005